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NOISE AND THE PORTABLE FORESTRY FIRE PUMP

by

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F O R E S T F I R E R E S E A R C H I N S T I T U T E

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CONTENTS

FOREWORD

This report is one of a series dealing with the operating characteristics of forestry fire pumps. The first report in the series FF-X-33 dealt with the effect of suction lift on the performance of a specific model of pump. Information Reports FF-X-36 and FF-X-38 also dealt with suction lift effects.

These books are not intended for the pump operator's use in the field but may be used for training. They are intended to provide the fire control officer with useful information on current models of pumps before they are assigned, with a crew, to a fire. This particular report deals with the risk of damage to an operator's hearing when using any of several common forestry fire pumps.

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INTRODUCTION

On any fire where a fire pump is in operation, one of the chief complaints by the operator is that the unit is too noisy. However, this fact has always been accepted because the portable forestry fire pump has proven a very beneficial tool on any fire operation. The noise produced by these pumps has been considered an occupational hazard which most pump operators have learned to accept. Probably, unknown to them, sustained exposure to noise levels produced by fire pumps may be causing irreversible hearing loss. However, in most cases, it is unlikely that an operator will subject himself to high noise levels for long periods of time because of his personal discomfort. Although, in some instances he may be inclined to station himself too close to a high decibel producing engine for no other reason than relief from biting insects which are avoiding the engine's exhaust fumes.

Portable forestry fire pumps, with two cycle engines, have long been suspected of producing noise levels far above what is normally considered a safe limit. Therefore, it was the intent of this study to determine what noise levels were being emitted by several commonly used fire pump models under different working conditions. The tests were undertaken by the Forest Fire Research Institute of the Canadian Forestry Service at the Petawawa Forest Experiment Station, Chalk River, Ontario during the summer months of 1972.

NOISE -- BACKGROUND

Noise and Decibels

Noise is commonly defined as "any unwanted sound" and the intensity of the noise is generally expressed in terms of decibels (dB). The decibel is not strictly a unit but is a ratio between two pressures, a measured sound pressure (SPL) and a reference sound pressure. The reference level can be referred to as "0 decibels" and this starting point is about the level of the weakest sound that can be heard by a person with very good hearing in an extremely quiet location. Typical points on the decibel scale are, for example, normal conversation at about 70 decibels and a boiler room around 90 decibels.

Noise radiating from a source in the open will decrease with distance and follow the inverse-square law whereby the noise level will decrease by 6 decibels for each doubling of the distance from the source. This will occur at distances greater than about 4 times the average linear dimension of the source of noise.

Noise Measurement

Sound level meters are used to measure noise levels. The scale on the meter usually measures to a maximum of 140 decibels which is at the threshold of pain for most individuals. Most meters are equipped with "weighting networks"

which are used to determine in a general way the frequency content of the noise. Frequency (Hertz or cycles per second), has quite a bit to do with how loud the noise sounds.

Three weighting networks were established, designated as A, B, and C. The main difference between them is that each discriminates against certain frequencies. For example, the A network discriminates quite severely against the very low frequencies, the B network moderately and the C network hardly at all. Therefore, if the measured sound level of a noise is much higher on C weighting than on A weighting, much of the noise is probably of low frequency. For simple noise ratings of a device, the A-weighted sound level is widely used and designated dB(A). All noise levels in this report will be of the A-weighted sound level.

Hearing Damage Risk

Most people associated with the operation of portable forestry fire pumps will have experienced at one time or another a temporary loss of hearing. This loss usually corrects itself within a reasonable time period. The recovery time may vary with the individual as some people are more susceptible to hearing loss than others. However, it is quite conceivable that many pump operators after years of manning fire pumps have suffered some permanent loss of hearing due to the nature of the job.

Fire pumps may be operated continuously for long periods of time with the operator stationed in close proximity to the unit. With the pump operating, usually at full throttle, there are no quiet periods to enable the operator's hearing to recover unless he makes frequent trips away from the unit.

It has been generally accepted that noise levels of 90 decibels and lower are relatively safe for the average individual for sustained periods of time without risking permanent hearing loss. Noise levels above 90 decibels are an altogether different matter. As the decibel level increases the safe time of noise exposure decreases rapidly to the point where an individual can only be safely subjected to the noise for a matter of minutes each day.

CHABA Criteria

In 1965, the Committee on Hearing, Bioacoustics and Biomechanics (CHABA) of the U.S. National Academy of Science presented a report (Kryter et al., 1966) showing the maximum sound levels and daily durations of noise exposure believed to be tolerable. The limits of allowed exposure were defined so as to preserve the ability to understand speech for the majority of persons exposed near-daily for 10 years or longer. The CHABA Criteria provide a direct means of determining acceptable exposure times to the noise levels generated by a pumping unit.

Table 1. ACCEPTABLE DAILY EXPOSURE TIMES FOR VARIOUS LEVELS OF FIRE PUMP NOISE BASED ON CHABA CRITERIA.

Noise Level at Operator's Ear Position dB(A)	Maximum Daily Duration of Single Continuous Exposure	Acceptable Intermittent Exposure. Total Time Per Day Not to Exceed 480 Minutes.
90	400 minutes	No practical restriction.
95	120 minutes	50 minutes exposed, 4 minutes away, etc.
*100	40 "	20 " " 7 " " "
*105	18 "	10 " " 10 " " "
*110	9 "	4 " " 10 " " "
*115	5 "	2 " " 7 " " "
*120	3 "	1 " " 4 " " "

*Typical noise levels at operator's ear while standing within 10 feet of several models of portable pumps operating at full throttle.

PURPOSE

This study was designed to determine what noise levels were being produced by several commonly used models of two-cycle portable forestry fire pumps with respect to the following:

1. The noise level produced in decibels for each pump model operating at several working pressures and engine rpm's at various distances up to 200 feet.

2. The dampening effect forest cover has on noise levels when compared to a treeless area.

3. The minimum "safe" distance for each pump model. The distance a pump operator, without benefit of ear protection, should station himself to ensure that he is not being subjected to more than the permissible 90 decibels.

4. The maximum noise level a pump operator is subjected to while adjusting a fire pump in operation.

5. The directional variation of noise levels radiating from a fire pump over a short distance.

PUMP MODELS SELECTED FOR TESTING

A total of 6 models of two-cycle engined centrifugal portable forestry fire pumps were tested. Each model is presently in common use across Canada. Although a few of the pump models are no longer manufactured, they still form part of the pump cache in many areas. They operate, for the most part, within a range of approximately 3,500 to 6,300 rpm. Due to the requirement of keeping each pump model as compact and portable as possible, their spark arresting mufflers have been kept to a minimum size. This fact has made the muffler on each model practically non-functional as a sound reducing device. In addition to the portable pumps, the four-cycle Coventry Climax Godiva pump as well as a typical backpacking Sprayer-Duster frequently used for herbicide spraying were also tested.

The following is a brief description of each pump model tested:

1. Wajax Mark I*

   The Wajax Mark I is a four stage centrifugal pump powered by a twin-cylinder, two-cycle, 9-horsepower Mercury engine.

2. Wajax Mark 2*

   The Wajax Mark 2 is a four stage centrifugal pump powered by a single cylinder, two-cycle, 8-horsepower Rotax engine.

3. Wajax Mark 3

   The Wajax Mark 3 is a four stage centrifugal pump powered by a single-cylinder, two-cycle, 8-1/2-horsepower Rotax engine. The Mark 3 has replaced both the Wajax Mark I and the Mark 2.

4. Gorman-Rupp Backpack

   The Gorman-Rupp Backpack is a single stage centrifugal pump powered by a single-cylinder, two-cycle, 8-horsepower Westbend engine.

5. Gorman-Rupp Bushwhacker

   The Gorman-Rupp Bushwhacker is a single stage centrifugal pump powered by a single-cylinder, two-cycle, 14-horsepower Rockwell JLO engine.

6. Terry T-7*

   The Terry T-7 is a four stage centrifugal pump powered by a single cylinder, two-cycle, 7-horsepower Homelite engine.

7. Coventry Climax Godiva

   The Coventry Climax Godiva is a single stage centrifugal pump powered by a four cylinder, four stroke, 30-horsepower Coventry Climax engine.

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*Pump models no longer being manufactured although parts are generally available.

8. Sprayer-Duster

The Sprayer-Duster, typical of many units in use, was a two-cycle, single cylinder air cooled engine. It is commonly operated while strapped to the back of the operator. They are frequently used to apply herbicides to control vegetation on fuel breaks or access road shoulders.

EXPERIMENTAL PROCEDURE

(1) Instruments Used for Noise Level Measurement

Bruel & Kjaer Type 2203 (Photo No. 1) and Type 2205 portable precision sound level meters were used to measure noise output. The meters were frequently checked for calibration using a Bruel & Kjaer sound level Calibrator Type 4230. The noise output was recorded for the A, B, and C weighting networks. This report, however, will only deal with the noise levels determined on the A weighting network.

(2) Test Site Description

Identical noise level recording procedures were followed with each test model at two contrasting sites. Their description is as follows:

Site "A", considered the control area, had few obstructions which might cause the noise generated by the test engines to be deflected or absorbed. It was situated on a level grass-covered area beside Centre Lake, a medium sized lake on the Petawawa Forest Experiment Station. Although somewhat removed from the actual test site, a fringe of alders bordered the lake's shoreline. However, no obstructions were present between the lake's shoreline where the pumps were operated and the stations from which the noise levels were measured. Photo No. 2.

Site "B", typical of many areas where a fire pump might be set up in a fire situation, was located within a well stocked conifer stand. Photo No. 3. The stand was predominantly white spruce and balsam fir with diameter sizes varying from 3 inches to 17 inches dbh. A creek (Younge's Creek) flowing through the stand provided a water source for the pumps. A small clearing was selected along the creek bank on which to set up the test units. Within 10 feet of the pump site, spruce and balsam branches extended to the ground creating a fairly dense screen between the pump site and the trees within the stand. Photo No. 4.

(3) Noise Level Recording Stations

At both Site "A" and Site "B" a line 200 feet in length was measured along the ground beginning at the pump site and extending back at a right angle away from the water source. Along each line at predetermined distances several noise level measurement stations were established. The first station was situated directly above the pump and the last at the 200-foot mark. Stations were also established at right angles to the remaining three sides of each test model at distances of 2 feet and 10 feet. Diagram I.

Photo No. 1. Precision sound level meter - Type 2203.

Photo No. 2. General view of open Site "A" - Centre Lake, P.F.E.S.

Photo No. 3. *Noise level measurements recorded within treed area - Site "B".*

Photo No. 4. *Noise level measurements recorded 2 feet above portable fire pump - Site "B".*

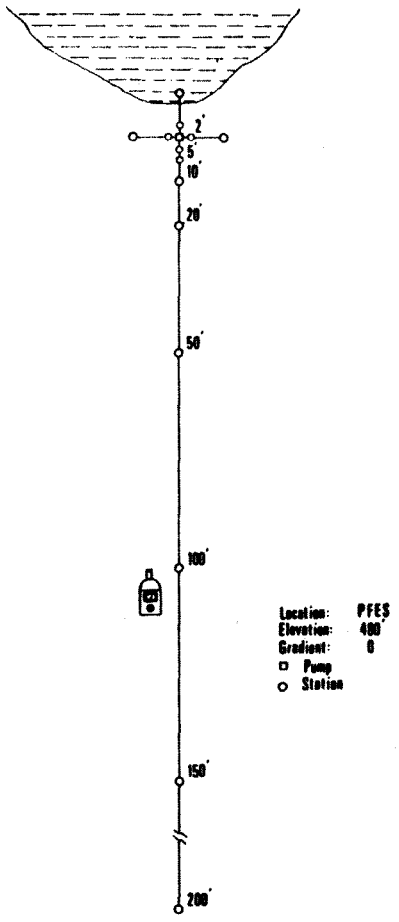

Diagram I. Noise level recording stations.

(4) Use of Sound Level Meter

At each station, the sound level meter was positioned 4 feet above the ground and aimed horizontally towards the noise source. The meter was either hand-held or mounted on a tripod with the operator observing the readings while standing to one side of the instrument. Noise level measurements were also recorded above and on each side of the test unit with the meter being held at a distance of 2 feet from the centre of the unit as well as above and 2 feet above the ground. Photo No. 4. These readings were recorded to obtain an indication of the maximum noise level a fire pump operator would be subjected to while adjusting the engine. In a few instances, spot measurements were taken within a few inches of the muffler to determine the maximum noise level generated by the engine.

(5) Pump Operation

Each test model operated was run successively at several pump discharge pressures and engine rpm's between free flow and shut-off pressure. A ball valve and a pressure gauge located at the pump's discharge outlet enabled the operator to regulate the pump's discharge pressure. The rpm for each selected test pressure was predetermined for each pump at the Hydraulics Laboratory using a Strobotac tachometer. For each discharge pressure and corresponding engine rpm the noise level in decibels, dB(A), was measured at all stations for both Sites "A" and "B".

RESULTS

(1) Noise Levels at Various Distances and Working Pressures -- Site "A"

The noise level produced by each model of portable forestry fire pump exceeded 90 dB(A) when measured 4 feet above the ground and directly over the pumping unit. All pumps (Godiva excluded) fell within a decibel range of between 107 to 116.5 dB(A) while operating at a pump discharge pressure of 100 psi. The maximum and minimum noise levels were produced by the Wajax Mark I and the Wajax Mark 3 respectively.

There was a rapid decline in noise level of approximately 12 dB(A) up to a distance of 10 feet from each pump model. However, at this distance none of the units were below 90 dB(A). Thereafter, as the distance from each pump was increased the decrease in noise level was more gradual until the final measurements were recorded at 200 feet. At 200 feet the noise level had reduced to between 56 and 72 dB(A) for each model. Table 3.

The effect of increased pump discharge pressure (free flow to shut-off) and engine speed (rpm) had little overall bearing on noise production. Measurements recorded for all units, 10 feet from each pump and 4 feet above the ground showed that the greatest variation in noise level occurred with the Gorman-Rupp Bushwhacker. The decibel rating at 10 feet increased from 98 dB(A) at near free flow (3,390 rpm) to 104 dB(A) at a pump discharge pressure of 250 psi (5,850 rpm). The average increase for the other models was approximately 3 dB(A). Table 2.

Table 2. THE EFFECT OF INCREASED PUMP DISCHARGE PRESSURE AND ENGINE rpm ON NOISE LEVELS [dB(A)] AT A DISTANCE OF 10 FEET AND 4 FEET ABOVE THE GROUND.

Pump Model	0-25 psi		100 psi		200 psi		250 psi	
	dB(A)	rpm	dB(A)	rpm	dB(A)	rpm	dB(A)	rpm
Wajax Mark I	112.0	4300	112.5	4500	113.5	5125	114.5	5575
Wajax Mark 2	96.0	4140	96.0	4340	97.5	5130	97.5	5670
Wajax Mark 3	93.5	4525	94.0	4700	94.0	5225	94.5	5650
Gorman-Rupp Backpack	101.5	4600	101.5	5100	105.0	6370	-	-
Gorman-Rupp Bushwhacker	98.0	3390	100.0	3820	102.5	5090	104.0	5850
Terry T-7	96.5	3650	97.5	3820	99.5	4750	101.0	5200

Table 3. NOISE LEVELS IN BOTH OPEN AND TREED SITES dB(A) vs DISTANCE AT PUMP DISCHARGE PRESSURE OF 100 psi.

1"		3/4"	3/4"	3/4"	1"	1"	3/4"	3/4"
Distance at 4 Feet Above Ground		Wajax Mark 1	Wajax Mark 2	Wajax Mark 3	Gorman-Rupp Backpack	Gorman-Rupp Bushwhacker	Terry T-7	Coventry Climax Godiva
0'	Open	116.5	107.0	108.5	113	109.0	109.5	99.0
dB(A)	Treed	114.5	107.0	107.0	112.5	110.0	109.5	-
5'	Open	117.5	100.5	99.5	106.0	104.5	103.5	97.0
dB(A)	Treed	112.0	96.5	97.0	108.0	102.0	101.0	-
10'	Open	112.5	95.5	94.0	101.0	100.0	97.5	94.0
dB(A)	Treed	110.0	93.5	93.0	100.0	98.0	96.0	-
20'	Open	107.0	91.5	90.5	98.0	95.5	94.5	88.0
dB(A)	Treed	101.0	85.0	85.5	93.0	90.5	90.0	-
50'	Open	100.0	84.0	82.0	90.0	88.0	88.0	78.5
dB(A)	Treed	79.0	69.0	68.5	76.5	74.0	73.5	-
100'	Open	89.5	74.5	73.0	82.0	80.0	80.0	70.0
dB(A)	Treed	72.0	59.0	60.5	66.0	65.5	65.5	-
150'	Open	80.0	66.0	64.0	73.0	71.0	69.5	63.0
dB(A)	Treed	70.0	56.5	58.5	64.5	62.0	63.5	-
200'	Open	72.0	60.5	56.0	67.0	65.0	64.0	59.0
dB(A)	Treed	66.0	55.0	54.5	61.5	59.0	59.0	-

(2) Noise Level Reduction Within a Forest Stand -- Sites "A" and "B"

Noise levels measured, following the same procedure in both the open and closed sites, showed that the presence of trees and shrubs, as would be expected, had a beneficial effect reducing noise levels. At a distance of 20 feet, the average noise level difference was 5 dB(A) for each pumping unit and at a distance between 50 and 100 feet a reduction of 15 dB(A) was maintained. For example, the Wajax Mark 3, operating at a pump discharge pressure of 100 psi, produced a noise level of 82 dB(A) at 50 feet in the open site whereas operating under the same conditions in the treed site the noise level was 68.5 dB(A). Similarly the Gorman-Rupp Bushwhacker produced 88 dB(A) in the open and 74 dB(A) in the trees. At distances beyond 100 feet the decibel difference gradually decreased until the final measurements were taken at 200 feet where the average difference for each pump model had reduced to 5 dB(A). Table No. 3.

These differences in noise levels are only an indication of the dampening effect trees and shrubs have on absorbing noise since a variation would occur depending upon the denseness of the forest cover.

(3) Minimum "Safe" Distance -- Sites "A" and "B"

As indicated earlier, sustained exposure to noise levels over 90 dB(A) are a definite hazard to an operator's hearing. Therefore, in order to lessen the chance of hearing loss from portable forestry fire pumps it would be beneficial to know the minimum "safe" distance an operator should station himself away from a particular pump model to ensure that he is not being subjected to more than an allowable 90 decibels.

Testing the different pump models in the open area revealed that the "safe" distance varied considerably between units. For example, while operating at a pump discharge pressure of 200 psi the "safe" distance for the Wajax Mark 3 was 17 feet whereas a distance of 90 feet was required before the noise level produced by the Wajax Mark I had reduced to 90 decibels. The "safe" distance for the other pump models fell within the above limits. Table No. 4.

Table 4. DISTANCE FROM NOISE SOURCE WHERE 90 dB(A) OCCURS - 200 psi.

Pump Model	Site "A" - OPEN	Site "B" - TREED	Difference
Wajax Mark I	90 feet	36 feet	54 feet
Wajax Mark 2	24 "	13 "	11 "
Wajax Mark 3	17 "	16 "	1 "
Gorman-Rupp Backpack	67 "	32 "	35 "
Gorman-Rupp Bushwhacker	58 "	28 "	30 "
Terry T-7	46 "	21 "	25 "
Coventry Climax Godiva*	24 "	-	-

*4-cycle engine - Godiva not operated on Site "B".

Compared with the open area, the treed site had a substantial effect upon reducing the "safe" distance. For most models this meant a reduction of approximately one-half the distance. The Gorman-Rupp Bushwhacker created a noise level of 90 dB(A) at a distance of 58 feet while operating in the open site whereas this distance was reduced to 28 feet in the wooded site. Table No. 4.

(4) Maximum Noise Levels -- Site "A"

The maximum noise levels a pump operator will be subjected to will naturally occur while kneeling beside a pump in operation. Noise level measurements recorded at the approximate location of an operator's ear while crouching over the machine (2 feet above the ground and directly over the pumping unit) showed that all pumps except the Godiva produced noise levels in excess of 110 decibels while operating at a pump discharge pressure of 150 psi. Table No. 5. Noise levels of this magnitude can be dangerous if the operator is required to spend considerable time in such close proximity to the pump without the aid of some form of approved ear protection.

Table 5. NOISE LEVELS 2 FEET ABOVE THE GROUND AND DIRECTLY OVER THE PUMP.

Pump Model	Noise Level - dB(A)
Wajax Mark I	121
Wajax Mark 2	115
Wajax Mark 3	112
Gorman-Rupp Backpack	122
Gorman-Rupp Bushwhacker	116
Terry T-7	119
Coventry Climax, Godiva	101

Noise level measurements taken within inches of a pump's muffler (Wajax Mark I) produced a reading on the sound level-meter in the vicinity of 140 dB(A). It is unlikely however, that a pump operator would subject himself to such a high noise level as it would be extremely painful.

(5) Directional Noise Radiation -- Site "A"

A fire pump, with its exhaust projected in one direction causes noise levels to vary over short distances depending upon which side of the pump the noise is measured. Measurements recorded at a distance of 10 feet away from the pump and 4 feet above the ground showed that noise levels were on the average 6 dB(A) higher on the exhaust side of the pump than in the opposite direction away from the muffler. Table No. 6.

Table 6. ENGINE NOISE LEVELS MEASURED ON OPPOSITE SIDES OF THE PUMP ENGINE.

Distance - 10 feet | Discharge Pressure - 150 psi

Pump Model	dB(A) measured on side of outlet	dB(A) measured on opposite side	Difference dB(A)
Wajax Mark I	116.0	107.5	8.5
Wajax Mark 2	100.5	95.5	5.0
Wajax Mark 3	101.5	93.5	8.0
Gorman-Rupp Backpack	122.5	115.5	7.0
Gorman-Rupp Bushwhacker	104.0	102.0	2.0
Terry T-7	102.5	98.0	4.5

(6) Sprayer-Duster -- Site "A"

The Sprayer-Duster is commonly used for spraying herbicides and insecticides. It is operated while either strapped to the back of an operator or mounted onto a tractor or truck.

While the apparatus was strapped to an operator's back, measurements taken within inches of both the right and left ear produced noise levels of 96 dB(A) and 94.5 dB(A) respectively. According to the CHABA Criteria in Table 1, an operator can safely run the machine for continuous periods of 50 minutes with 4 minutes in between. While operating at half throttle the noise levels were 79.5 dB(A) and 77.5 dB(A) at both the right and left ear respectively.

CONCLUSIONS

1. Each model of portable forestry fire pump tested produced noise levels well in excess of 90 dB(A). An operator, while adjusting many of the pump models operating at full throttle will be subjected to noise levels greater than 115 dB(A).

2. The result of increasing engine rpm and pump discharge pressure while operating at full throttle did not significantly increase the noise level.

3. The presence of trees and shrubs had a beneficial effect, reducing noise levels at various distances from each pump model.

4. The "safe" distance or the distance away from an operating pump where noise levels have decreased to 90 dB(A) varied with each pump model. It occurred at a minimum distance of 17 feet with one model and 90 feet with another.

5. Noise levels when measured a short distance (10 feet) from each pump model and at a right angle to each side produced different noise levels. As would be expected, the highest noise level was generated from the exhaust outlet side of each pump model.

RECOMMENDATIONS TO PRESERVE HEARING

In order to lessen the possibility of permanent hearing loss caused by the operation of portable forestry fire pumps one of the following should be complied with:

(1) Reduce Pump Engine Noise Levels

Protection agencies at the present time have little control over the excessive noise levels produced by the fire pumps in their cache. However, with the present emphasis on noise pollution as a health hazard, it might be fair to demand that the manufacturers of pumps make every effort to reduce the noise levels of their products to a more acceptable level. Ideally, the noise level should be no greater than 90 decibels at the operator's ear while performing some function at the pump. In return for a quieter engine, a protection agency might possibly have to accept a slightly less efficient pumping unit as well as one that is bulkier due to the installation of a more efficient muffler system.

(2) Reduce the Duration of Exposure

Since all pumps tested generated noise levels capable of causing a permanent loss of hearing, the necessity for minimizing the duration of exposure is of prime importance. For example, the average noise level a pump operator is exposed to while kneeling beside a pump in operation is in the vicinity of 115 dB(A). This level, according to the CHABA Criteria in Table 1, would allow an operator to work at the pump for a maximum of 2 minutes followed by a quiet period of 7 minutes or no more than a daily single continuous exposure of 5 minutes. Pumps operating in the 120 dB(A) range would necessitate a quiet period of 4 minutes out of every 5 minutes or a maximum daily continuous exposure of only 3 minutes. Therefore, it is very critical that an operator, without benefit of ear protection, spend a minimum of time at or near the pump. As a general rule, it would be reasonable to suggest that the operator station himself at least one hose length (100 feet) away from the pumping unit when not required to make engine adjustments or perform other functions at the pumping site.

(3) Protect the Exposed Personnel by the Use of Ear Protection Devices

Ear protection is the surest safeguard against hearing loss while operating portable forestry fire pumps. As emphasized earlier in the report, all pumps tested present a definite risk for permanent hearing loss from the high noise levels emitted by their engines. Therefore, it should be mandatory, as it is with the wearing of hard hats, that all pump operators be provided with and be required to wear some form of approved ear protection. Ear protectors should be part of the checklist of equipment found in every pump tool box.

Ear plugs reduce the noise level from 20-30 decibels. However, ear plugs must form an airtight seal in order tc obtain the full noise reduction. Muffs, which cover the entire ear are usually more dependable since they are subject to fewer uncertainties of fit and positioning.

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